Ultrafast Coherent Diffractive Imaging with X-ray Free-Electron Lasers

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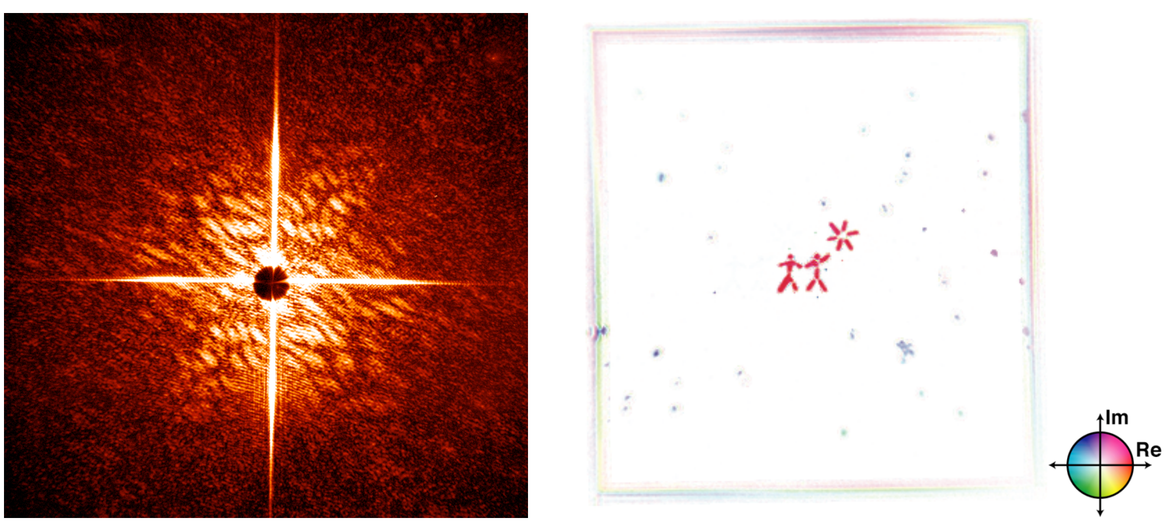
The ultrafast pulses from future X-ray free-electron lasers (XFELs) will enable extraordinary new capabilities in the imaging of non-periodic objects at extremely high spatial and temporal resolution. Single-particle diffractive imaging with XFELs may provide near-atomic resolution. In this method radiation damage limits are overcome by obtaining coherent diffraction patterns from objects with pulses that are shorter than the timescales for radiation-induced changes to occur in the object at the resolution length scale. The specimen would be completely destroyed by the pulse, but that destruction will only happen after the pulse has passed through the object. A collaboration between LLNL, Uppsala University, SLAC, DESY, and LBNL has been following a program of research at FLASH, the soft-X-ray FEL at DESY, Hamburg, to develop the experimental methods for FEL diffractive imaging. In particular we have:

- Demonstrated that low-noise coherent diffraction patterns can be recorded with single pulses as short as 10 fs duration, and that these can be phased to give high-resolution images;
- Performed time-resolved coherent diffractive imaging to examine the dynamics of objects irradiated by FEL and laser pulses. These studies support models that suggest that pulse durations of up to 50 fs could be used to attain 0.3 nm resolution;
- Demonstrated single-pulse diffractive imaging of particles injected into vacuum from solution, traveling across the beam at about 200 m/s.

These results, which confirm the basic principles of single-particle imaging, will be presented. Plans for experiments at future short-wavelength X-ray FELs will be discussed.



Single 25-fs pulse coherent diffraction pattern recorded at FLASH (left), and reconstructed complex-valued image (right). The image width is 20 micron. From Chapman *et al*. Nature Physics **2** 839-843 (2006).